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WPŁYW NIERÓWNOŚCI KOŃCZYN DOLNYCH NA WYNIK POMIARU KĄTA ROTACJI TUŁOWIA ZA POMOCĄ SKOLIOMETRU U PACJENTÓW ZE SKOLIOZĄ IDIOPATYCZNĄ

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STRESZCZENIE
Wstęp
Skoliometr jest powszechnie używany w badaniach przesiewowych skolioz. Dotąd nie wyjaśniono w jakim stopniu badanie skoliometrem jest zależne od skośnego ustawienia miednicy.
Cel
Celem pracy było sprawdzenie zależności wyników pomiaru kąta rotacji tułowia od skośnego ustawienia miednicy.
Materiał i Metody
Grupę badaną stanowiło 25 dziewcząt ze skoliozą idiopatyczna w wieku 15,6±1,8 lat. Grupę kontrolną stanowiło 25 dziewcząt bez skoliozy w wieku 14,2±0,9.
Kąt rotacji tułowia (KRT) mierzony był w teście Adamsa, w pozycji stojącej przy pomocy skoliometru Bunnella. KRT był mierzony na czterech poziomach: piersiowym proksymalnym, piersiowym, piersiowo-lędźwiowym/lędźwiowymi oraz na wysokości kolców biodrowych tylnych górnych. Pomiary były powtarzane u tych samych pacjentów z na tych samych poziomach kręgosłupa z uniesieniem lub obniżeniem miednicy przy pomocy podkładek pod stopę o grubości 1cm lub 2 cm.
Wyniki
Wartości pomiaru KRT zmieniały się znacząco w po zastosowania podkładek 1cm lub 2cm. Wzrost wartości KRT był obserwowany po stronie uniesionej, a zmniejszenie po obniżonej. Różnica zależna była od wielkości uniesienia miednicy oraz od badanego odcinka kręgosłupa: 2°-5.1° na poziomie kolców biodrowych tylnych górnych ; 1.5°-4.5° w odcinku lędźwiowym; 1.2° - 3.8° w odcinku piersiowym i 0.7° to 2.4° w odcinku piersiowym proksymalnym.
Wnioski
Pomiar kata rotacji tułowia skoliometrem jest wrażliwy na skośne ustawianie miednicy, zwłaszcza w odcinku lędźwiowym kręgosłupa. Powinno być to brane pod uwagę podczas badań przesiewowych skolioz z użyciem skoliometru.

Słowa kluczowe: skoliometr, badanie przesiewowe skolioz, kąt rotacji tułowia, skolioza idiopatyczna

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THE EFFECT OF THE LIMB LENGTH DISCREPANCY ON THE SCOLIOMETER MEASURE OF THE ANGLE OF TRUNK ROTATION IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

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SUMMARY

Introduction

The scoliometer is widely used for scoliosis screening. It is not clear whether and how much the scoliometer measurements are sensitive to a non-level pelvis.

Aim

The aim of the study was to check the effect of the pelvic obliquity on the angle of trunk rotation.

Material and Methods

The study group consisted of 25 girls with Idiopathic scoliosis , aged 15.6±1.8 years and the control group consisted of 25 healthy girls aged 14.2±0.9 years. Angle of trunk rotation was measured with Bunnell scoliometer in standing Adams' forward bending test. The ATR values were noted at four levels: proximal thoracic, main thoracic, thoracolumbar/lumbar, and at the level of posterior superior iliac spines. The measurements were repeated in the same subjects and at the same levels, while the subject had the pelvis raised or lowered with a lift 1cm or 2cm thick.

Results

The values of ATRs changed significantly while the 1cm or 2cm lifts were used. Increased ATRs were observed on the raised side of the pelvis, or decreased on the lowered side. The difference from standing position depended on the lift thickness and the spinal level: 2°-5.1° at the PSIS level; 1.5°-4.5° within the lumbar spine; 1.2° - 3.8° within the thoracolumbar spine, and 0.7° to 2.4° within the high thoracic spine.

Conclusions

The ATR measurement with the Bunnell scoliometer is sensitive to a non-level pelvis, especially within the lumbar spine. This should be taken into consideration when using the scoliometer in school screening.

Keywords: Scoliometer, scoliosis screening, angle of trunk Rotation, idiopathic scoliosis

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Introduction

Idiopathic scoliosis (IS) is a structural three-dimensional deformity of the spine, with lateral curvature greater than 10 degrees as measured on standing radiograph, according to the Cobb method, with vertebral rotation. IS arises in otherwise healthy children at or around puberty. The IS prevalence ranges from 1% to 3% in adolescent population(Weinstein et al., 2008).

Longitudinal studies revealed that small curvatures remain stable for the lifetime while severe scoliosis, above 50 degrees of the Cobb angle, tend to progress and have a negative impact on patient's health and quality of life (Weinstein et al., 2003). Thus, the severe curvatures require operative treatment with surgical stabilization of the operated part of the spine (Kotwicki et al., 2013).

There are strong evidences that IS may be successfully treated with conservative methods (Weinstein et al., 2013). The main aim of the conservative treatment is prevention of the curvature progression (Weiss et al., 2008). Thus, the early diagnosis of IS, in immature patients, is crucial to achieve good results (Kotwicki et al., 2013).

Taking into consideration of the prevalence of the AIS, possible implications of the disease and existing effective methods of conservative treatment, early detection is required. Thus, the screening program could be considered.

The approach to the screening of IS is a complex subject and varies around the world from mandatory screening programs, through voluntary programs, to lack of such screening at all (Grivas et al., 2007). There is scientific evidence to support the value of scoliosis screening with respect to technical efficacy, clinical, program and treatment effectiveness, however, there is insufficient evidence to make a statement with respect to cost effectiveness (Labelle et al., 2013).

Patients are screened with Adams' forward bend test using a scoliometer. Definitive diagnosis is made with measuring the Cobb angle on a standing coronal radiograph (Weinstein et al., 2008, Grivas et al., 2007). According to Labelle et al. the scoliometer is currently the best tool available for scoliosis screening. (Labelle et al., 2013) The scoliometer is an inclinometer that measures the asymmetries between the two sides of the trunk by measuring axial rotation in degrees. The angle of trunk rotation (ATR) values represent the rib hump in the thoracic part of the spine or the muscle prominence in the lumbar part of the spine. Both prominences develop as a consequence of the spinal column rotation. They are the most prominent at the apex of the curvature. Their value correlates with the Cobb angle measures (Labelle et al., 2013, Stolinski and Kotwicki, 2012, Korovessis and Stamatakis, 1996, Larson et al., 2018, Coelho et al., 2013).

Scoliometer is reliable, sensitive and specific tool for both IS detection and follow-up examination, so it allows decreasing radiation exposure(Bunnell, 1984, Grivas et al., 2006, Larson et al., 2018, Murrell et al., 1993, Amendt et al., 1990). However, the measures are examiner-dependent, and may be influenced by factors such as incorrect lower limbs position or pelvic obliquity (Grivas et al., 2007, Patias et al., 2010, Kotwicki et al., 2007, Chowanska et al., 2012).

Aim

The aim of the study was to check the effect of the pelvic obliquity on the angle of trunk rotation.

Material and methods

The study group consisted of 25 IS girls. The diagnosis of idiopathic scoliosis was confirmed in all patients by an experienced orthopedic surgeon. The patients underwent clinical and radiological examination. Only patients with double major curvatures: right thoracic and left lumbar and with Cobb angle of 35° or more, were included into the study group.

The control group consisted of 25 healthy girls. All volunteers from the control group underwent a clinical examination with ATR evaluation with scoliometer in Adams' bending test. Only girls with ATR of 3° and below were included into the study. In this group, the radiological examination was not performed.

The study protocol consists of five series of measurements of ATR with Bunnell scoliometer in Adams' forward bending test for each girl from both the study group and the control group.

In each case the ATR values were noted at four levels of the spine: proximal thoracic (Th3-Th4), main thoracic (Th8-Th9), thoracolumbar/lumbar (Th12-L1,2) and at the level of posterior superior iliac spines (PSIS).

The measurements were repeated in the same subjects and at the same levels of the spine in the following five positions: 1) with the pelvis leveled (assessed at the level of anterior superior iliac spines and posterior superior iliac spines), 2) with the foot pad of 1 cm thick under the left foot, 3) with the foot pad of 2 cm thick under the left foot, 4) with the foot pad of 1 cm thick under the right foot, 5) with the foot pad of 2 cm thick under the right foot.

One examiner performed all measurements. The rotation of the pelvis into the right side was marked with the '+' and the rotation of the pelvis into the left side was marked with the '–' symbol.

For each parameter mean values, standard deviation and the limit values were established. Normal distribution of data was analyzed with the Kolomogorov-Smirnov test. The p-level of 0.05 was considered significant. The data was compared with the subsequent groups, t-test was used to compare means. The data was analyzed using the GraphPad InStat software 3.06 (Graph Pad Software, San Diego, CA, USA).

Results

The mean age of girls with IS was 15.6 ± 1.8 years in the study group and 14.2 ± 0.9 years in the control group, p=0.001. There was no significant difference in height between the groups. The girls from the study group were slightly heavier than the girls from the control group 57.1kg vs. 52.0kg, p=0.045. Anthropometric data is presented in Table 1.

In the study group the mean Cobb angle was 60.7° in the thoracic part of the spine and 54.4° in the lumbar part of the spine (Table 1.

Table 1. Anthropometric description of the groups

	Study group N=25	Control group N=25	P-value
Age (years)	15.6 ± 1.8 (13.3 - 19.9)	14.2 ± 0.9 (12.6 - 16.5)	0.001
Height (cm)	166,0 ± 6,4 (156.0 - 180.5)	164.8 ± 5.1 (156.0 - 173.0)	0.46
Sitting height (cm)	82.7 ± 4.9 (73.0 - 94.0)	84.5 ± 3.5 (78.0 - 88.0)	0.14
Weight (kg)	57.1 ± 11.0 (40.0 - 85.0)	52.0 ± 5.9 (43.0 - 65.0)	0.045
Thoracic curvature Cobb angle (°)	60.7 ± 17.3 (38.0 - 93.0)	-	-
Lumbar curvature Cobb angle (°)	54.4 ± 18.0 (35.0 - 92.0)	-	-

The ATR values changed while the 1cm or 2cm lifts were, Table 2 for the study group, Table 3 for the control group. Increased ATR values were observed on the raised side, decreased values on the lowered side, Table 2 and Table 3.

Table 2. Angle of trunk rotation of patients with idiopathic scoliosis in simulation of limb length discrepancy

	ATR (°)			
	Th3 –Th4 (mean ±SD min÷max)	Th8 -Th9 (mean ±SD min÷max)	Th12 - L1,2 (mean ±SD min÷max)	PSIS (mean ±SD min÷max)
Leveled pelvis	5.9 ± 5.2 -6.5 ÷15.0	15.3 ± 8.3 -7.0 ÷ 28.5	-7.5 ± 4.2 -16.0 ÷ 1.0	0.1 ± 0.4 0.0 ÷ 2.0
+1cm left	4.7 ± 5.0 -7.0 ÷ 14.5	13.3 ± 8.4 - 9.5 ÷ 27.0	-9.8 ± 4.3 -17.5 ÷ -3.0	-2.4 ± 1.1 -4.5 ÷ -0.5
+2cm left	3.5 ± 4.8 -8.0 ÷ 12.0	11.5 ± 8.4 -10.0 ÷ 26.5	-12.0 ± 4.8 -20.0 ÷ -4.0	-5.0 ± 1.2 -8.0 ÷ -3.0
+1cm right	6.9 ± 5.2 -5.5 ÷ 15.0	16.8 ± 8.3 -5.0 ÷ 29.0	-5.2 ± 4.7 -15.0 ÷ 4.0	2.3 ± 1.1 1.0 ÷ 5.0
+2cm right	8.2 ± 5.6 -5.0 ÷ 17.5	18.5 ± 8.1 -3.0 ÷ 30.0	-3.0 ± 4.4 -13.0 ÷ 5.0	5.0 ± 1.1 3.0 ÷ 7.0

ATR – angle of trunk rotation, PSIS-posterior superior iliac spines

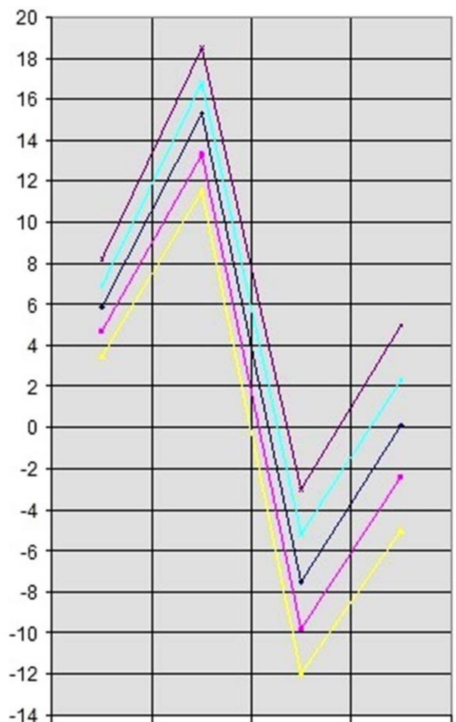
Table 3. Angle of trunk rotation of control group in simulation of limb length discrepancy

	ATR (°)			
	Th3 –Th4 (mean ±SD min÷max)	Th8 -Th9 (mean ±SD min÷max)	Th12 - L1,2 (mean ±SD min÷max)	PSIS (mean ±SD min÷max)
Leveled pelvis	-0.4 ± 1.2	-0.1 ± 1.2	0.1 ± 1.6	0.0 ± 0.0

	-3.0 ÷ 3.0	-2.5 ÷ 2.5	-3.5 ÷ 3.0	0.0 ÷ 0.0
+1cm left	-1.1 ± 1.4 -4.5 ÷ 0.0	-1.3 ± 1.6 -5.0 ÷ 2.0	-1.4 ± 1.7 -5.5 ÷ 1.5	-2.1 ± 1.1 -4.0 ÷ -0.5
+2cm left	-1.8 ± 1.4 -5.5 ÷ -1.0	-2.4 ± 1.7 -6.5 ÷ 1.5	-3.2 ± 2.2 -9.0 ÷ 0.5	-4.3 ± 1.7 -7.5 ÷ -1.5
+1cm right	0.5 ± 1.3 -2.5 ÷ 4.0	1.6 ± 1.8 -2.0 ÷ 6.0	2.3 ± 2.1 -1.5 ÷ 6.0	2.0 ± 1.2 0.5 ÷ 4.5
+2cm right	1.3 ± 1.5 -2.0 ÷ 5.0	3.3 ± 2.2 -0.5 ÷ 8.5	4.5 ± 2.5 0.0 ÷ 8.0	4.6 ± 1.9 2.0 ÷ 8.5

ATR – angle of trunk rotation, PSIS-posterior superior iliac spines

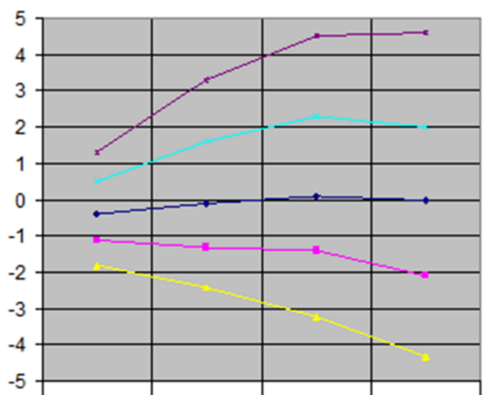
The difference from initial position (with the pelvis leveled) depended on lift thickness and spinal level. The evaluation of the LLD simulation in the group of patients with IS revealed that with the foot lift of 1cm the mean differences of ATR were 2.5° and 2.2° at the PSIS level; 2.3° within the thoracolumbar spine; 1.5° and 2.0° within the thoracic spine; 1.0° and 1.2° within the high thoracic spine. When the foot lift of 2cm was applied the mean differences of ATR were 4.9° and 5.1° at the PSIS level; 4.5° within the thoracolumbar spine; 2.8° and 3.2° within the thoracic spine; 2.3° and 2.4° within the high thoracic spine, Figure 1.



	Th3-Th4	Th8-Th9	Th12-L1,2	PSIS
Pelvis leveled	5.9	15.3	-7.5	0.1
+1cm left foot	4.7	13.3	-9.8	-2.4
+2cm left foot	3.5	11.5	-12	-5
+1cm right foot	6.9	16.8	-5.2	2.3
+2cm right foot	8.2	18.5	-3	5

Figure 1. The difference of the angle of trunk rotation in patients with idiopathic scoliosis in a simulation of limb length discrepancy.

The evaluation of the LLD simulation in the control group revealed that with the foot lift of 1cm the mean differences of ATR were 2° and 2.1° at the PSIS level; 1.5° and 2.2° within the thoracolumbar spine; 1.2° and 1.7° within the thoracic spine; 0.7° and 0.9° within the high thoracic spine. When the foot lift of 2cm was applied the mean differences of ATR were 4.3° and 4.6° at the PSIS level; 3.3° and 4.4° within the thoracolumbar spine; 2.3° and 3.4° within the thoracic spine; 1.4° and 1.7° within the high thoracic spine, Figure 2.



	Th3-Th4	Th8-Th9	Th12-L1,2	PSIS
Pelvis leveled	-0.4	-0.1	0.1	0
+1cm left foot	-1.1	-1.3	-1.4	-2.1
+2cm left foot	-1.8	-2.4	-3.2	-4.3
+1cm right foot	0.5	1.6	2.3	2
+2cm right foot	1.3	3.3	4.5	4.6

Figure 2. The difference of the angle of trunk rotation in the control group in a simulation of limb length discrepancy.

Discussion

The purpose of this study was to draw attention to the problem and a possible influence of the pelvic obliquity (rotation in the coronal plane) on measurements of ATR. To our knowledge such evaluation has never been published. We believe that pelvic obliquity is a common issue, which is underestimated and often unnoticed. One of the most common reasons of pelvic obliquity is the leg length discrepancy (LLD). It is reported that in the populations without impairments LLD affects 4.0% - 8.0% (Drnach et al., 2012, Brady et al., 2003). Although, the LLD should be equalized to leveled pelvis it may be unnoticed especially during screening programs. Inadequate measurements of these parameters may influence the screening examination or clinical follow-up and subsequently diagnosis and treatment. The scoliometer examination in Adams' bending test is recommended for scoliosis screening. Thus, the understanding the of the biomechanical implication of the LLD seems to be relevant.(Labelle et al., 2013) This study shows how important is the influence of the LLD on the scoliometer measurements when the pelvis is not leveled.

For assessment of the impact of the LLD on IS we decided to include patients with moderate or severe IS with Cobb angle of 35° or more to avoid a possible bias associated with small rotation in small curvatures, as well as to avoid possibility of inclusion of the non-idiopathic scoliosis to the study group. Taking into consideration the diversity of scoliosis types, we decided to focus on one type with right thoracic curve to avoid dispersion of the results and to analyze ATR changes in both lumbar and thoracic levels.

Taking into consideration that all patients had similar, double curvature pattern of the IS the Th8 – Th9 and Th12 – L1,2 the levels of the measurements corresponded to the apexes of the structural curvatures. The level of Th3 – Th4 shows the proximal compensatory curvature and the PSIS level shows the level of pelvis and reflects the simulation of LLD due to the foot pad placed under the foot.

What is more, we performed the same measurements in the group of healthy girls to assess whether the straight spine reveals a similar response for the unleveled pelvis as the spine in IS.

The study group was noticeable younger, however in the study concerning clinical examination the difference of 1.4 year should not have an significant influence on the result, especially if the height was comparable and the difference in weight was at the level of significance.

We can confirm that each change in the pelvis level provokes changes in the trunk transverse position in Adams' bending test. There is a proportional correlation of the thickness of the footpad, the pelvis obliquity and the ATR changes.

The greatest ATR changes were noted in the lumbar spine, smaller in the thoracic part and the smallest in the proximal thoracic. Thus, the impact of the pelvis obliquity on ATR was opposite to the distance of the evaluated spine segment to the pelvis. This is why we can consider it to be a compensation developing along the spine.

Thus, the actual ATR readings may reveal values decreased or increased depending on the side of pelvic obliquity. The impact of the pelvic obiquity will be more significant on the lumbar curvature than on the thoracic one.

The ATR difference due to LLD was up 4.5° with 2 cm and 2.3° with 1cm of discrepancy Therefore it may have important influence on the qualification of the child to either the group of healthy children or to the group of children with IS suspicion. The scoliosis suspicion is usually considered as 7° ATR. The normal values are considered up to 3° ATR. The pathological threshold is quite close to normal ATR values (Bunnell, 1984).

This bias may occur in both situations: as a false positive in children with LLD without IS and as a false negative in children with IS and shortening of the limb on the same side to the curvature convexity. The highest risk of such a bias is present in the lumbar the spine and therefore the assessment of the pelvis level should never be omitted in the ATR evaluation.

The results of this study reveal limitations of the scoliometer examination, however, such an error is easy to avoid, when an examiner is aware of such a possibility. Precise evaluation of the pelvis level prior to scoliometer evaluation or/and additional measure performed at the level of PSIS in the Adams' bending test is the best solution of this pitfall.

In case of oblique pelvis, the pelvis leveling is obligatory should be leveled with the footpads. Also the sitting position for examination may be applied (Chowanska et al., 2012, Kotwicki et al., 2007).

The influence of LLD was analyzed in radiological examination of the spine in standing position (Janusz et al., 2016, Papaioannou et al., 1982, Sekiya et al., 2018). However, there is very limited information about the implications of LLD on the trunk rotation during the Adams' bending test. The examination protocol indicates that examination should be performed with the leveled pelvis. But until now the analysis of the alteration of the trunk asymmetry in the transverse plane due to pelvic obliquity has not been performed.

Conclusions

The ATR measurement with the Bunnell scoliometer is sensitive to a non-level pelvis, especially within the lumbar spine. This should be taken into consideration when using the scoliometer in school screening.

Measurement of the pelvis level at the posterior superior iliac spines in Adams' forward bending test with a scoliometer may help to avoid an error in measurements due to limbs length discrepancy.

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